Producing a new generation of regional climate model projections:
The CORDEX framework

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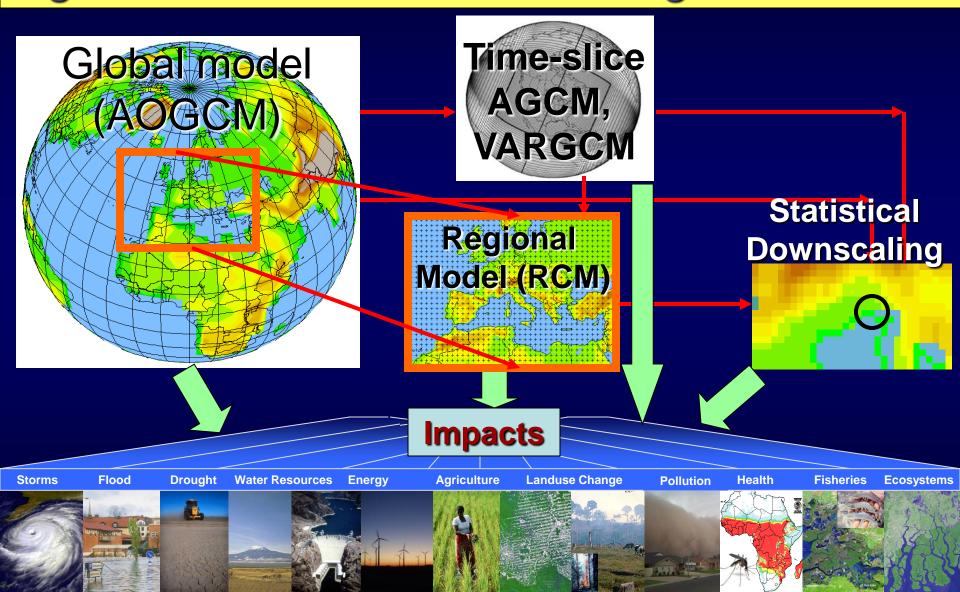High resolution modeling workshop, ICTP 10-14 August, 2009

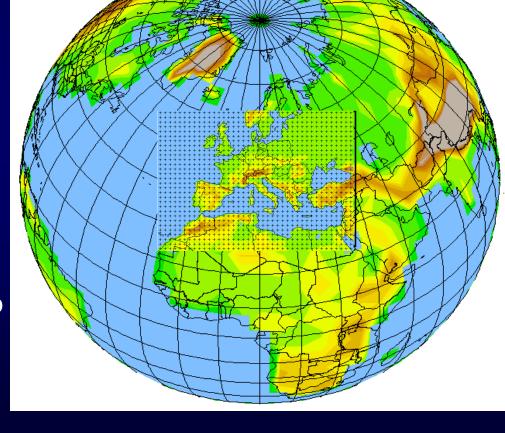# Various tools are available to "downscale" regional and local climate change information

"Nested" Regional Climate Modeling

Motivation: The resolution of GCMs is still too coarse to capture regional and local climate processes

Technique: A "Regional Climate Model" (RCM) is "nested" within a GCM in order to locally increase the model resolution.
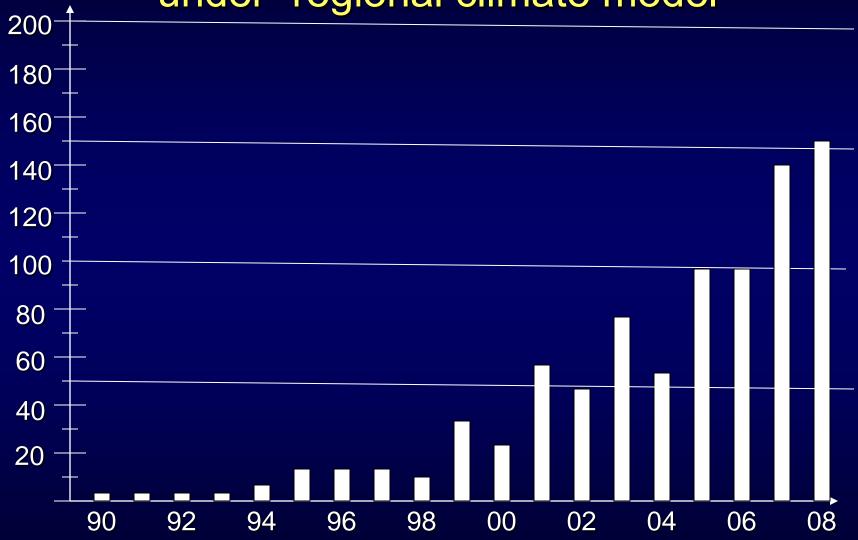
- Initial conditions (IC) and lateral boundary conditions (LBC) for the RCM are obtained from the GCM ("One-way Nesting") or analyses of observations.

Strategy: The GCM simulates the response of the general circulation to the large scale forcings, the RCM simulates the effect of sub-GCM-grid scale forcings and provides fine scale regional information
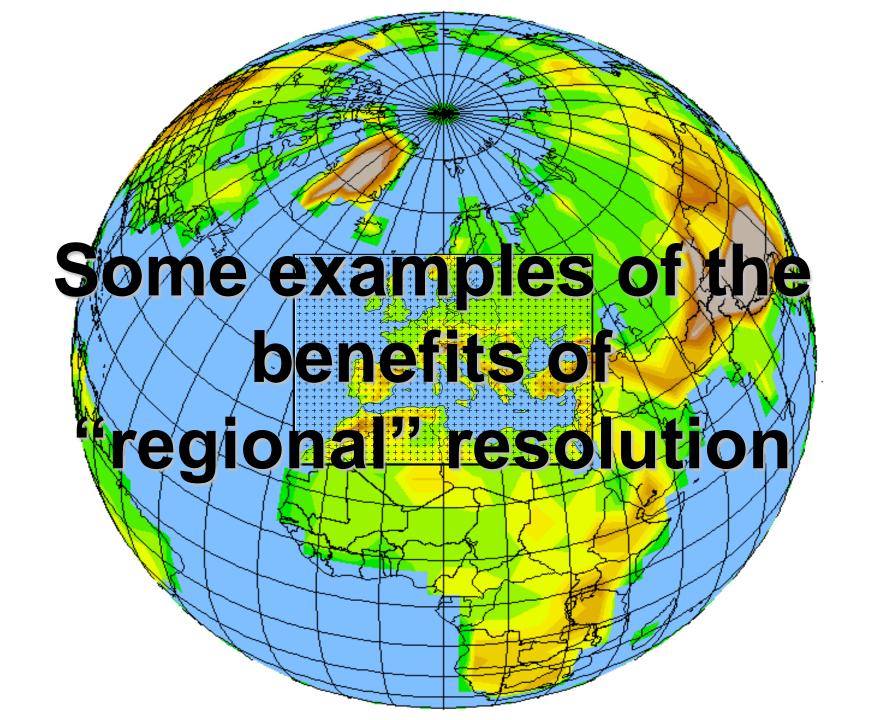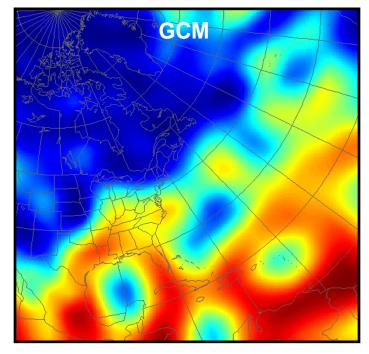
- Technique borrowed from NWP
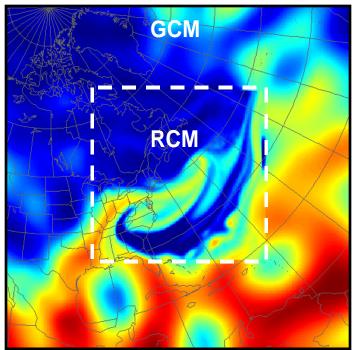
Number of papers in the ISI under "regional climate model"

Some key projects and literature

- Review papers: Giorgi and Mearns (1991), McGregor (1997), Giorgi and Mearns (1999), Giorgi et al. (IPCC 2001), Leung et al. (2003), Mearns et al. (2003), Wang et al. (2004), Giorgi (2006), Laprise (2007)

- European projects: PRUDENCE, AMMA, ENSEMBLES, CECILIA, CLARIS, ACQWA

- Intercomparison projects: PIRCS, RMIP, NARCCAP, NEWBALTIC, ARCMIP, PLATIN,ARC, NAMAP, QUIRCS,Transferability

- Special issues: JGR 1999; JMSJ 2004; TAC 2006; CC 2007; MAP 2004, 2008; CCH 2006; MET.-ZEIT. 2008

Some examples of the benefits of "regional" resolution
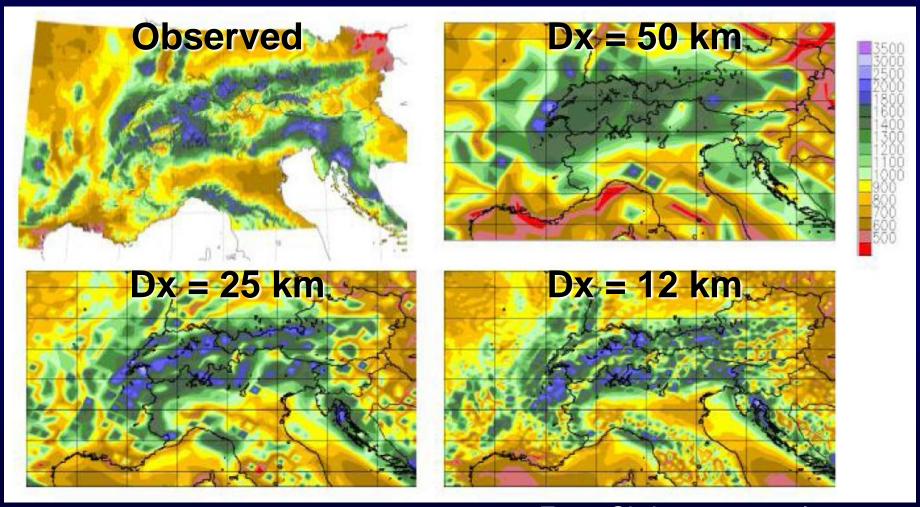
Dynamical Downscaling
Generation of small scales by a high-resolution RCM driven by low-resolution GCM data (900 hPa specific humidity)

Large scales **Short scales**

From Laprise et al. (2007)

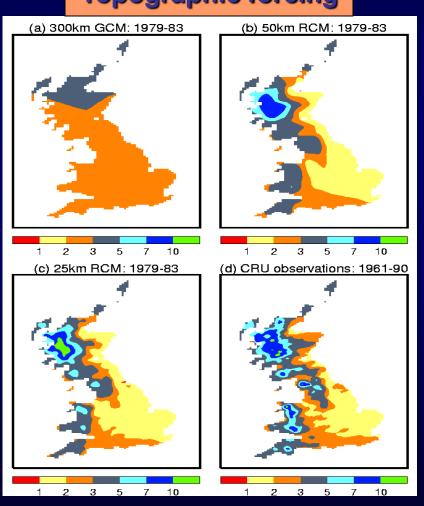# RCM simulation of precipitation at different resolutions over the Alps (1960-1990)

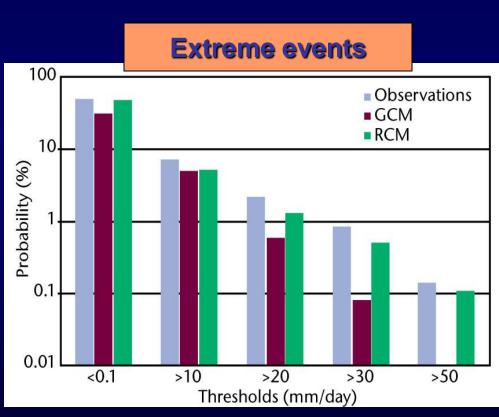## Mean annual precipitation (mm/day)
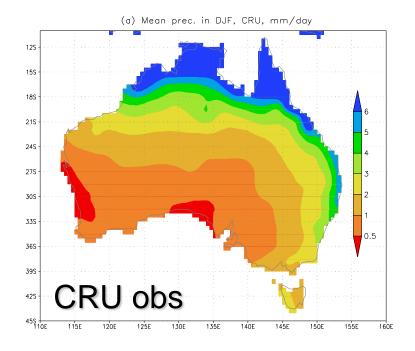
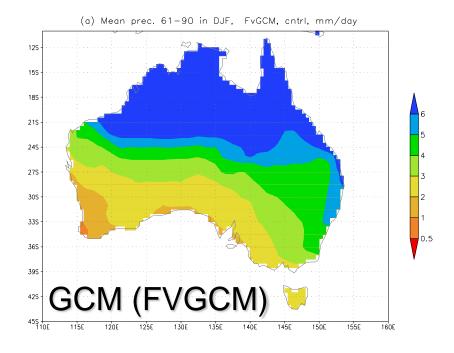

From Christensen et al. 2005

The added value of RCMs

Topographic forcing

(a) 300km GCM: 1979-83   (b) 50km RCM: 1979-83

(c) 25km RCM: 1979-83   (d) CRU observations: 1961-90

Extreme events

Courtesy of R. Jones

(a) Mean prec. in DJF, CRU, mm/day

CRU obs

(a) Mean prec. 61-90 in DJF, FvGCM, cntrl, mm/day
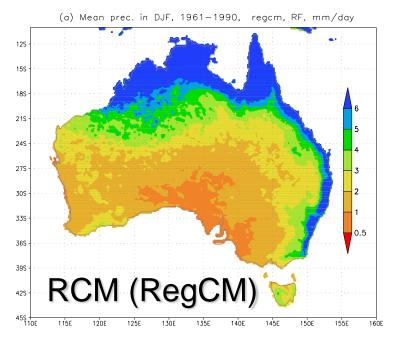
GCM (FVGCM)

(a) Mean prec. in DJF, 1961-1990, regcm, RF, mm/day

RCM (RegCM)
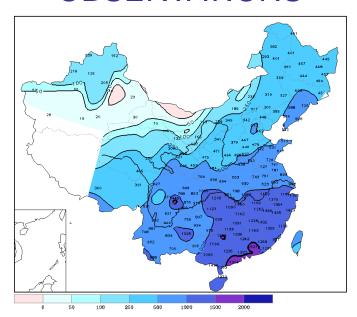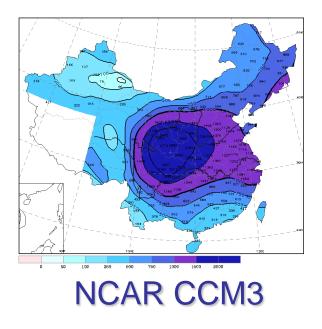
DJF precipitation
30-year nested
RCM simulation,
1961-1990,
20 km grid spacing
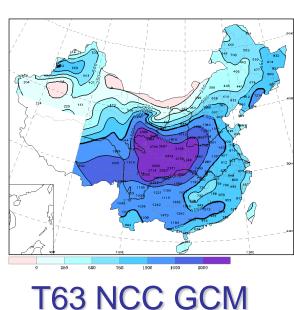
OBSERVATIONS

Simulation of east Asia monsoon precipitation by GCMs has been traditionally very difficult
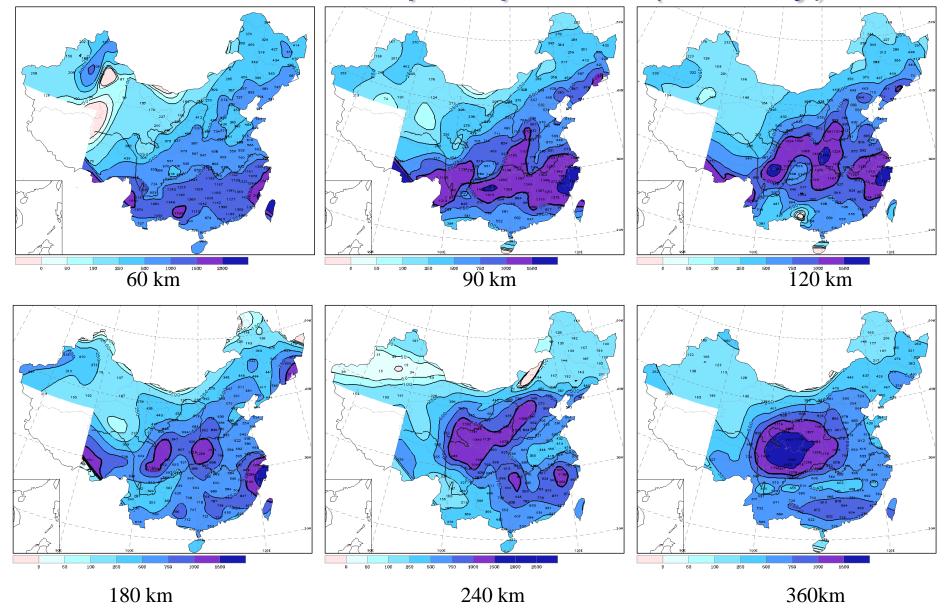
(Mean annual precipitation is shown;

Gao et al. 2006)

NCAR CCM3

T63 NCC GCM

CSIRO GCM

Mean annual precipitation (mm/day)

60 km

90 km

120 km

180 km

240 km

360km
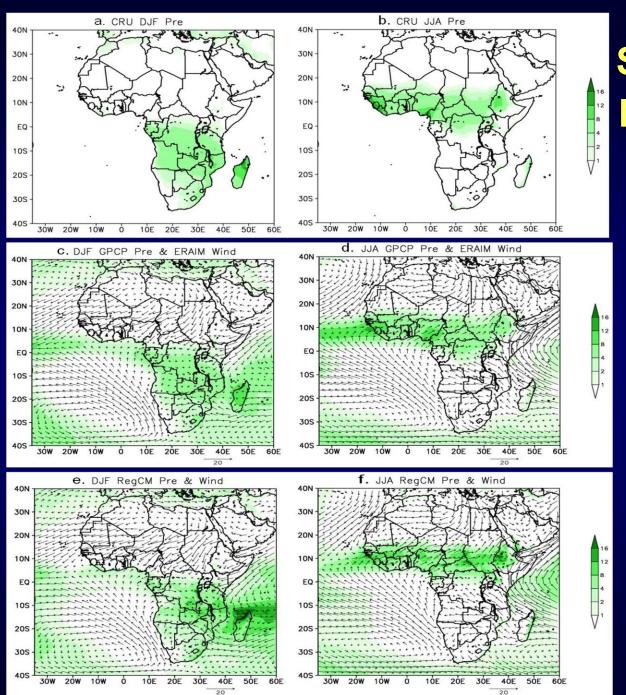
Simulation of mean precipitation for an all-Africa domain
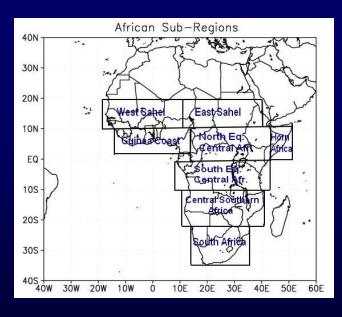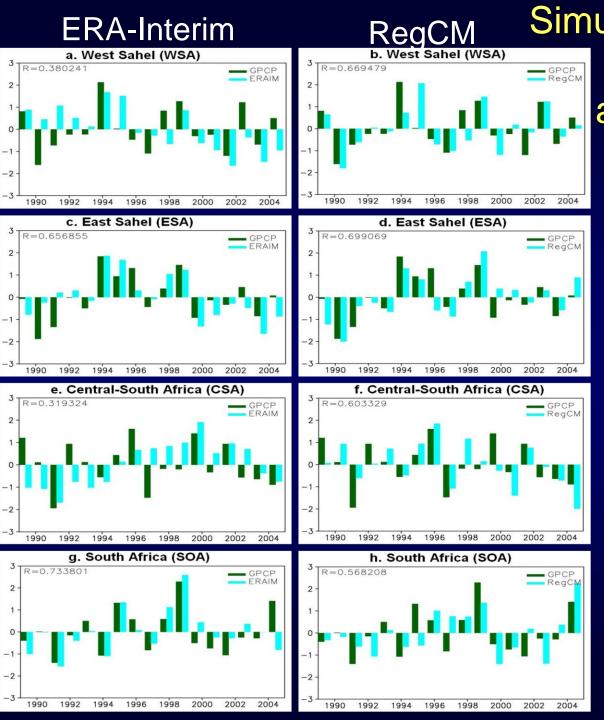
ERA-Interim LBC (1989-2007)
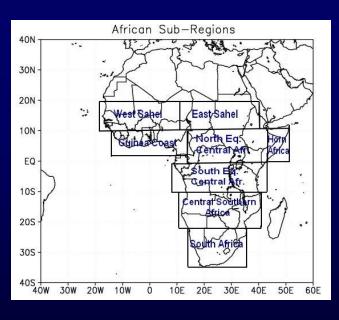
Sylla et al. 2009

Simulation of seasonal precipitation for an all-Africa domain

ERA-Interim LBC (1989-2007)

Sylla et al. 2009

ERA-Interim | RegCM
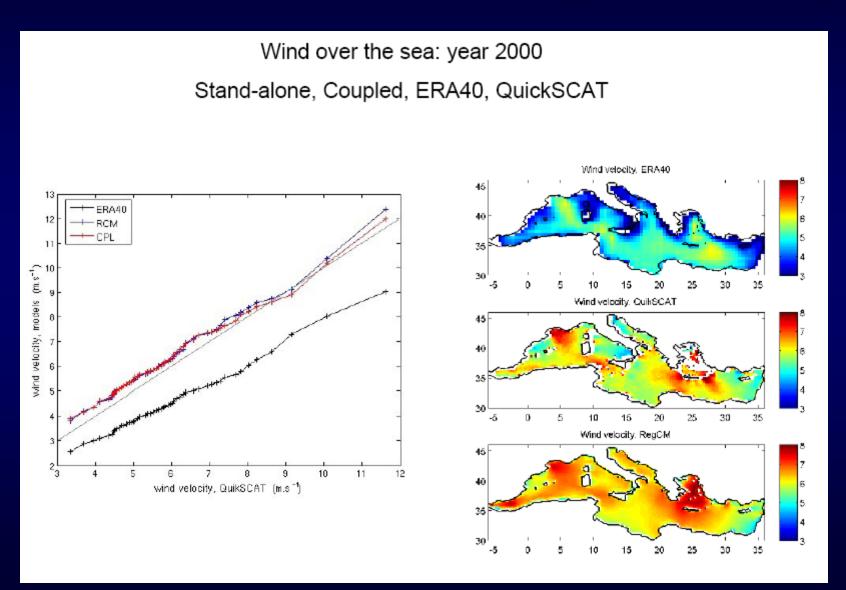
Simulation of interannual variability for an all-Africa domain

ERA-Interim LBC (1989-2007)
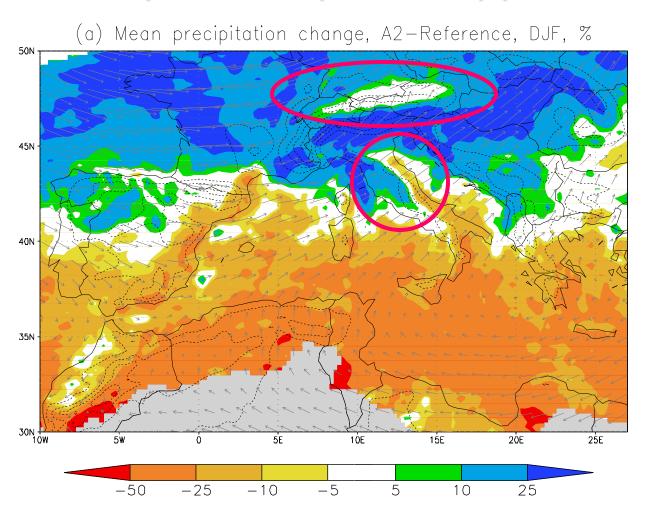
Sylla et al. 2009

Surface winds in a coupled regional RCM for the Mediterranean 30 km resolution, 1960-1990, ERA40 LBC (Artale et al. 2009)
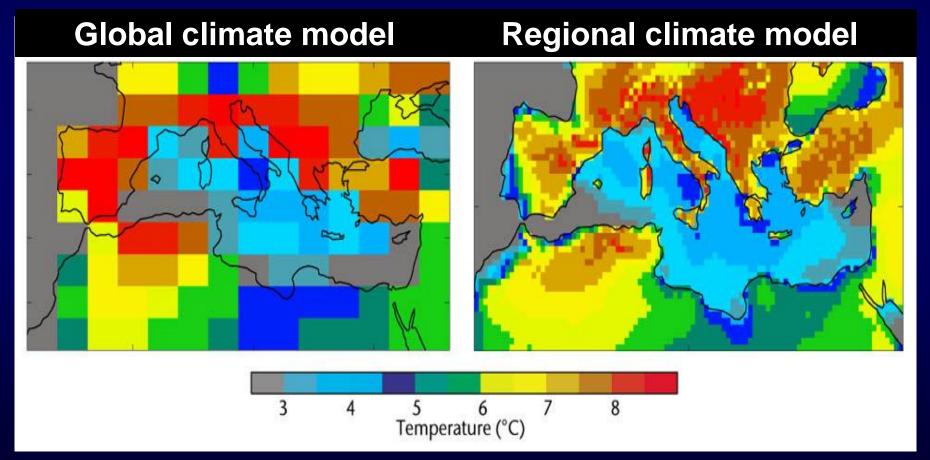
Do high resolution forcings affect the climate change signal? Topography

DJF Precipitation change (%)- dx=20 km
A2 (2071-2100) – Control (1961-1990) (Gao et al. 2006)

(a) Mean precipitation change, A2-Reference, DJF, %
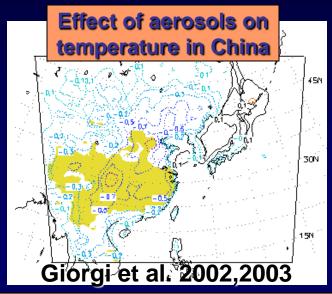
Do high resolution forcings affect the climate change signal? Coastlines
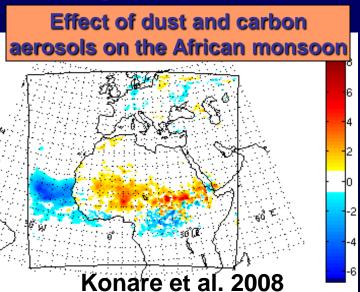
Summer temperature change, 2080s, A2

Global climate model

Regional climate model

Temperature (°C)
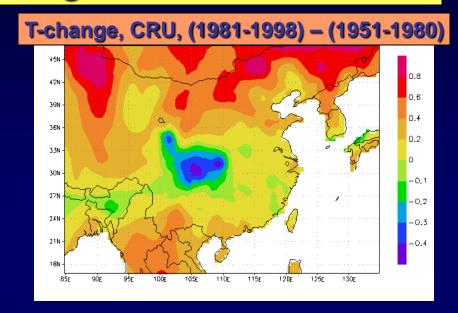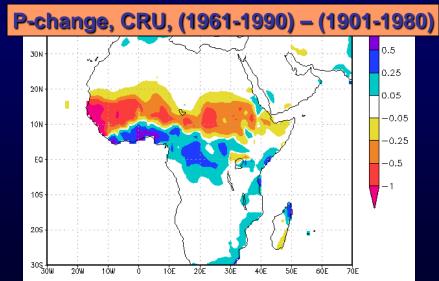
(Courtesy of R. Jones)

Do high resolution forcings affect the climate change signal? Aerosols

Effect of aerosols on temperature in China

Giorgi et al. 2002,2003

T-change, CRU, (1981-1998) – (1951-1980)

Effect of dust and carbon aerosols on the African monsoon

Konare et al. 2008

P-change, CRU, (1961-1990) – (1901-1980)
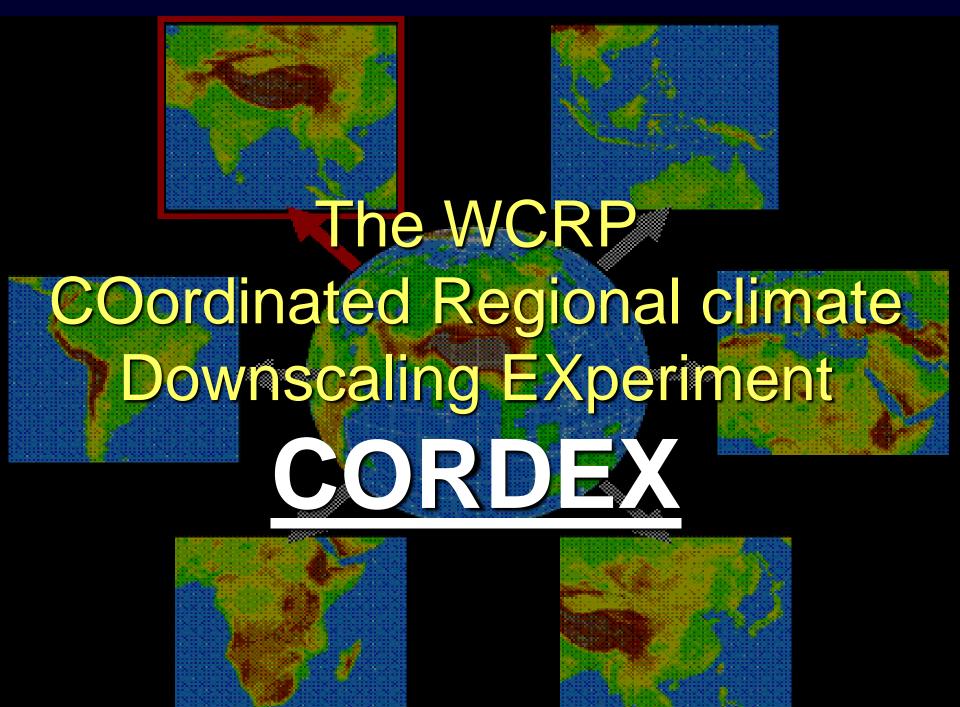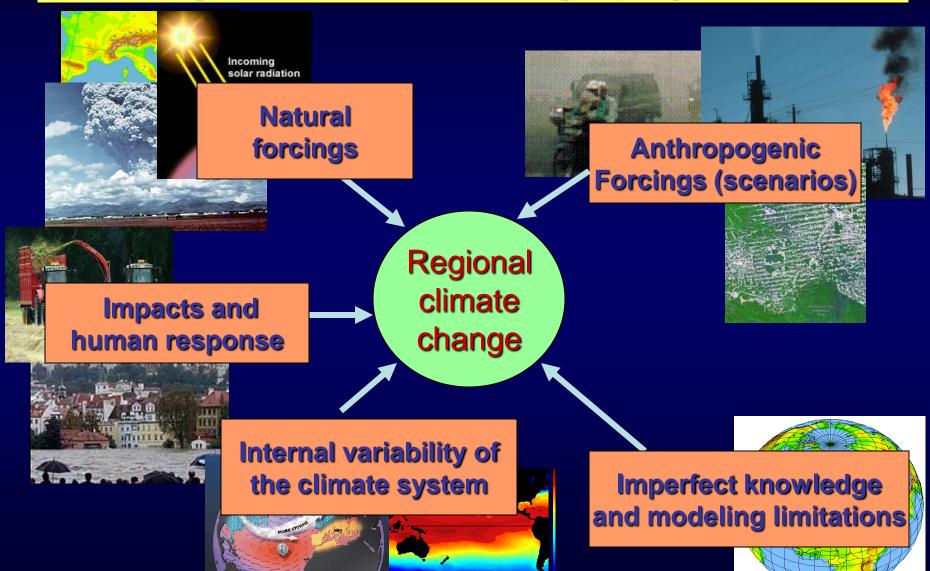
Regional Climate Models: "State of the art"
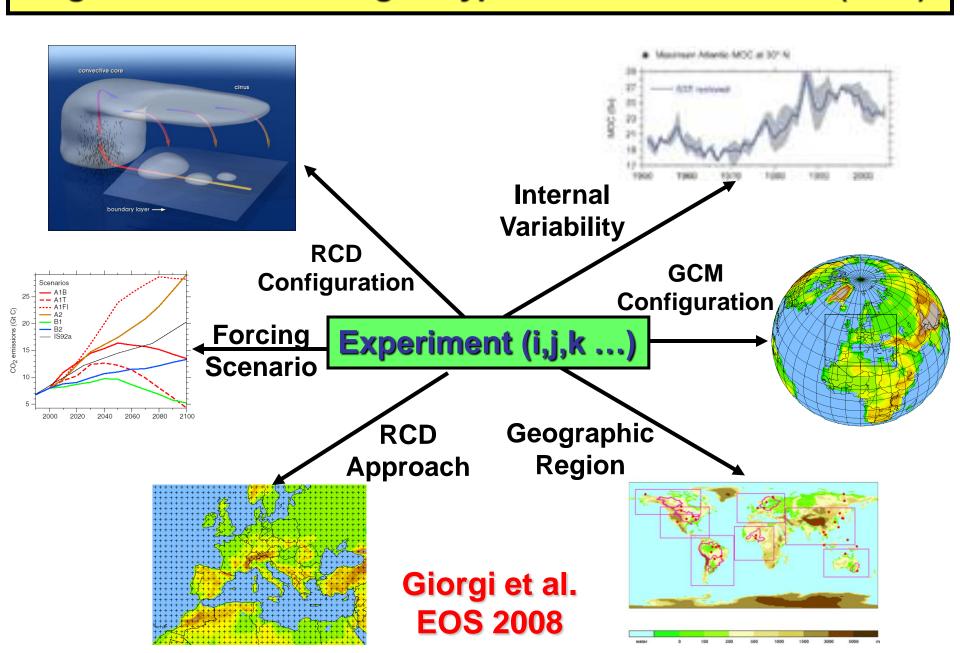
- Many RCMs today available, some of them "portable" and used by wide communities (e.g. RegCM, PRECIS, RSM, WRF)
- Grid spacing of 10-30 km (sub-10 km for some models);
- Upgrade to non-hydrostatic, cloud-resolving frameworks in order to go to sub-10 km resolutions
- Decadal to centennial simulations the "accepted standard"
- Virtually all regions of the World have been simulated
- Encouraging results from some two-way nested experiments
- Several RCM coupling efforts under way, including atmosphere, ocean, aerosol, and biosphere components
- Wide range of applications
    - Process studies, paleoclimate, climate change, seasonal prediction, impacts, climate-aerosol interactions, air-sea interactions, land-atmosphere feedbacks

The WCRP
COordinated Regional climate
Downscaling EXperiment
CORDEX

There are many sources of uncertainty to regional climate change projection

Natural forcings

Anthropogenic Forcings (scenarios)

Regional climate change

Impacts and human response

Internal variability of the climate system

Imperfect knowledge and modeling limitations
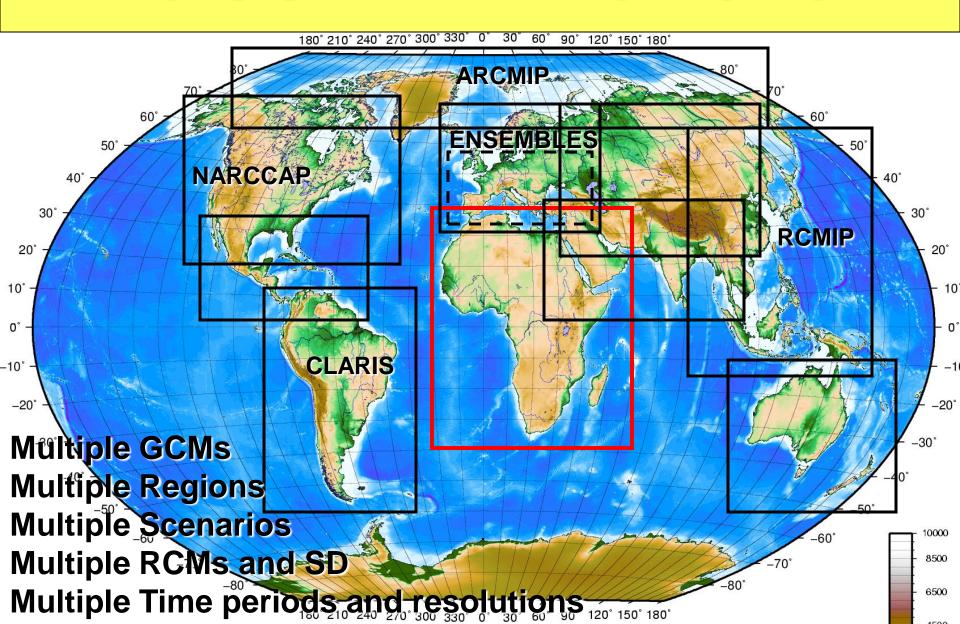
Regional Climate Change "Hyper-Matrix Framework" (HMF)

RCD Configuration

Internal Variability

GCM Configuration

Forcing Scenario

Experiment (i,j,k …)

RCD Approach

Geographic Region

Giorgi et al. EOS 2008
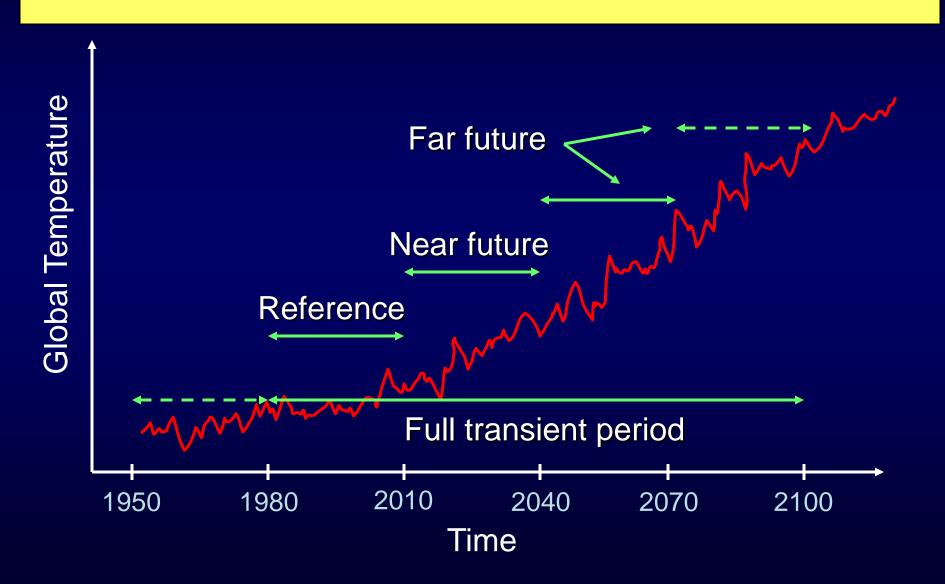
CORDEX: COordinated Regional climate Downscaling EXperiment

- Task Force on Regional Climate Downscaling (TFRCD)
  - Evaluate and possibly improve different regional downscaling techniques (Model Evaluation Framework, AMIP-like)
  - Design a common framework for the next generation RCD-based climate change projections for input to impact/adaptation work (Model Projection Framework, CMIP-like)
  - Facilitate the engagement of the end-user community and the scientific community from developing countries

The CORDEX Framework

ARCMIP

ENSEMBLES

NARCCAP

RCMIP

CLARIS
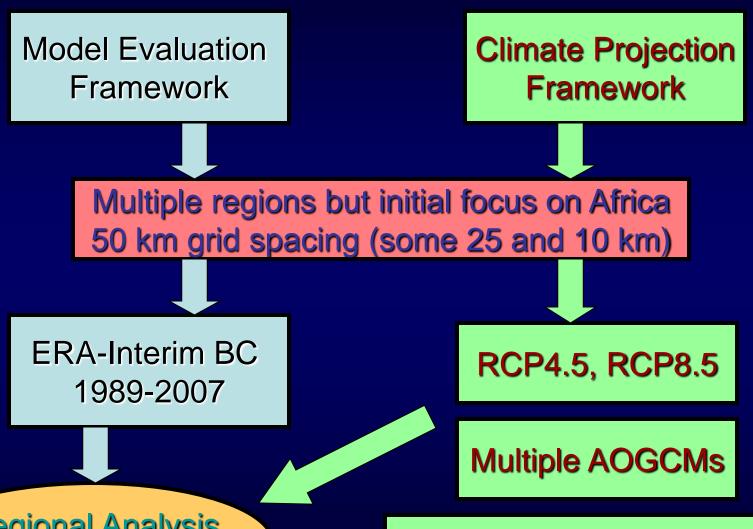
Multiple GCMs
Multiple Regions
Multiple Scenarios
Multiple RCMs and SD
Multiple Time periods and resolutions

CORDEX Phase I experiment design

Model Evaluation Framework

Climate Projection Framework

Multiple regions but initial focus on Africa
50 km grid spacing (some 25 and 10 km)

ERA-Interim BC
1989-2007

RCP4.5, RCP8.5

Multiple AOGCMs

Regional Analysis
Regional Databanks

1951-2100
1981-2010, 2041-2070, 2011-2040

Some final considerations

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- RCMs can enlarge the modeling community and as such have an important "educational" role
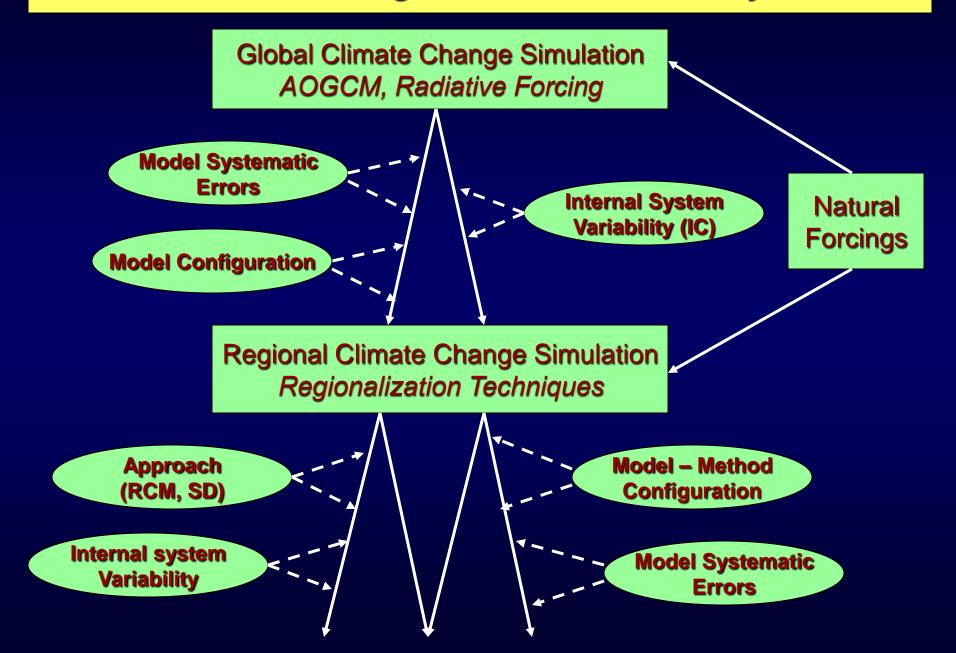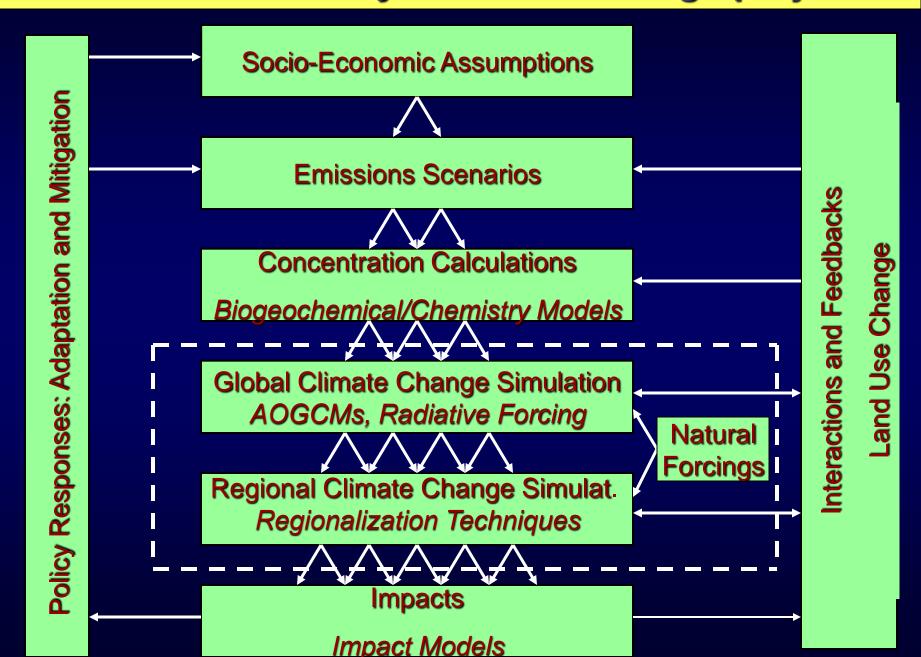
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- CORDEX will provide an important benchmark framework for the downscaling community.

THANK YOU

Climate simulation segment of the uncertainty cascade

Global Climate Change Simulation
AOGCM, Radiative Forcing

Model Systematic Errors

Model Configuration

Internal System Variability (IC)

Natural Forcings

Regional Climate Change Simulation
Regionalization Techniques

Approach (RCM, SD)

Model – Method Configuration

Internal system Variability

Model Systematic Errors
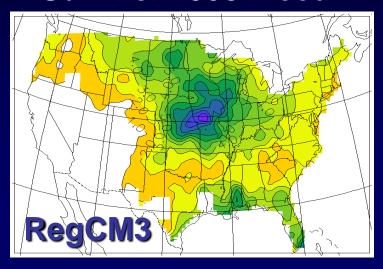
Cascade of uncertainty in climate change projection

Policy Responses: Adaptation and Mitigation

Socio-Economic Assumptions

Emissions Scenarios

Concentration Calculations
Biogeochemical/Chemistry Models

Global Climate Change Simulation
AOGCMs, Radiative Forcing

Natural Forcings

Regional Climate Change Simulat.
Regionalization Techniques

Impacts
Impact Models

Interactions and Feedbacks

Land Use Change

Simulation of extreme precipitation

Summer 1993 Flood

RegCM3

Summer 1993 Flood

Observations

Summer 1988 Drought

RegCM3

Summer 1988 Drought

Observations

JJA Precipitation

GPCP/ERAINT

RegCM ERAINT

GPCP

RCA35 ERAINT

mm/day

0 2 4 6 8 10 12 14 16 18